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CLIMATE CHANGE SCENARIO OVER GANGTOK

1. Climate change is now-a-days a great concern for many scientists, researchers and policy makers as the implications of the climate change perceived are detrimental and adverse to the survival of the mankind. The present environmental policy on climate change suggests climate change as change in global climate. The United Nations Framework Convention on Climate Change (UNFCCC) states that the climate change is due to human activities. The few impacts of climate change were global warming, melting of glaciers, rise in sea levels, sub-mergence of coastal areas, floods and increase in frequency of heavy rainfalls. The present state of our understanding suggests that even though climate change can be caused by natural causes like, change in the orientation of the earth's axis, variation in the solar radiation reaching the surface of the earth, variation in the distance between sun and the earth, massive volcanic eruptions, changes in the rotational speeds of the earth etc. The climatic variability now seen as purely due to man made activities like large scale pumping of green house gas emissions from industry into atmosphere, combustion associated with the daily human activities.

Many scientific and governmental conventions and conferences sought reduction in the greenhouse gas emissions both from developed and developing countries so as to retard climate change. The Inter governmental Panel on Climate Change (IPCC) in its third assessment report mentioned the average global temperature has increased by about 0.6 °C. The Inter governmental Panel on Climate Change (IPCC) on climate change in its fourth report concluded that the climate change is unequivocal. In the present scenario, the climate change over single station, Gangtok has been taken up to find out presence of any noticeable trends in monthly, seasonal, annual maximum temperature, minimum temperature and rainfalls.

2. The available meteorological data for the period 1957 – 2005 in respect of monthly maximum temperature, monthly minimum temperature and monthly rainfall has been collected from the records of the Meteorological Center, Gangtok. A few missing values in the data so selected have been substituted with long period average values (1957-2005). From this seasonal and annual figures and some statistics related to them have been computed.

3. In this paper, seasonal Kendall test was performed on the data sets like monthly, seasonal and

annual maximum temperature, minimum temperature and rainfalls. In the seasonal Kendall test trend is calculated using regression analysis. The data series are classified according to month, season and annual series. Computed the sign of all the values within the given set. For example, sign (value $X - \text{Value } Y$) where $X > Y$. Convert the positive signs thus obtained to +1, negative signs to -1 and tied up values to 0. Added all this 'S_i'. Computed the variance (S_i) of the resulted value of the added using the formula

$$\frac{[N(N-1)(2N+5) - \sum \{X_{ip} - (X_{ip} - 1)(2X_{ip} + 5)\}]}{18.0}$$

Here 'N' is the number of monthly values and 'X_{ip}' number of tied data in the 'pth' tied group for the 'ith' value. Computed the sum of the all added up values for all the months 'S'. Computed the variance (S) by summing up all the variances 'S_i' as calculated above. Computed the test statistic |Z|.

$$Z = (S-1) / \text{Variance } (S)^{0.5}; \text{ if } S > 0$$

$$Z = 0; \text{ if } S = 0$$

$$Z = (S+1) / \text{Variance } (S)^{0.5}; \text{ if } S < 0$$

The null hypothesis is $|Z| > Z_{a/2}$ where 'a' is the selected significant level.

In this paper, the Kendall-Tau correlation coefficient was computed using

$$\tau = \frac{4p}{N(N-1)} - 1$$

Here '+1' indicates perfect agreement; '-1' indicates perfect disagreement; '0' indicates independence.

The seasonal Kendall is a non-parametric test and no assumptions are required about normality and constant variance. An increasing trend exists when significantly more data pairs increase than decrease, a decreasing trend exists when significantly more data pairs decrease than increase and if same number of pairs increase and decrease with the same frequency no trend exists.

4. Brazdil *et al.*, (1995) through their study showed that the daily maximum and daily minimum temperatures exhibited positive trends during the winter, summer & spring. The temperatures exhibited negative trend in autumn over non-urban stations over Czech and Slovic republics. The temperatures also showed significant positive trend over mountainous regions. Here in this study, before discussing the trends in the

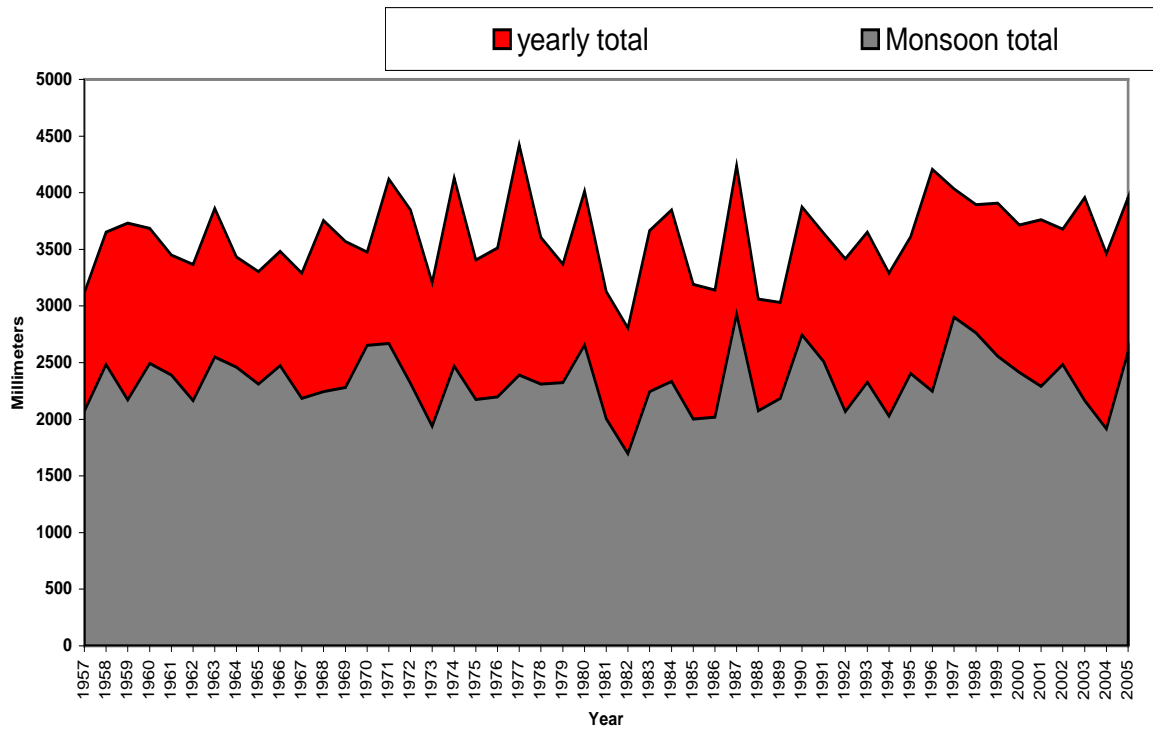


Fig. 1. Showing annual and summer monsoon rainfalls over Gangtok 1957-2005

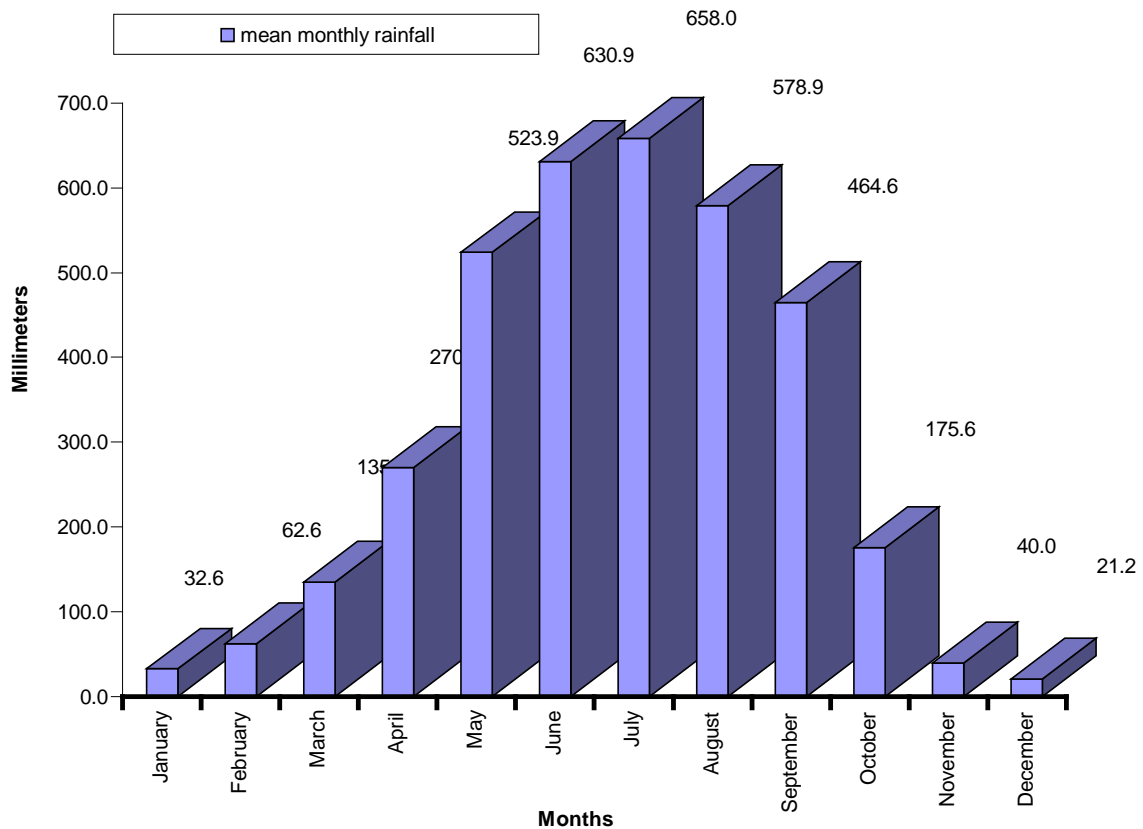


Fig. 2. Showing mean monthly rainfall over Gangtok (1957-2005)

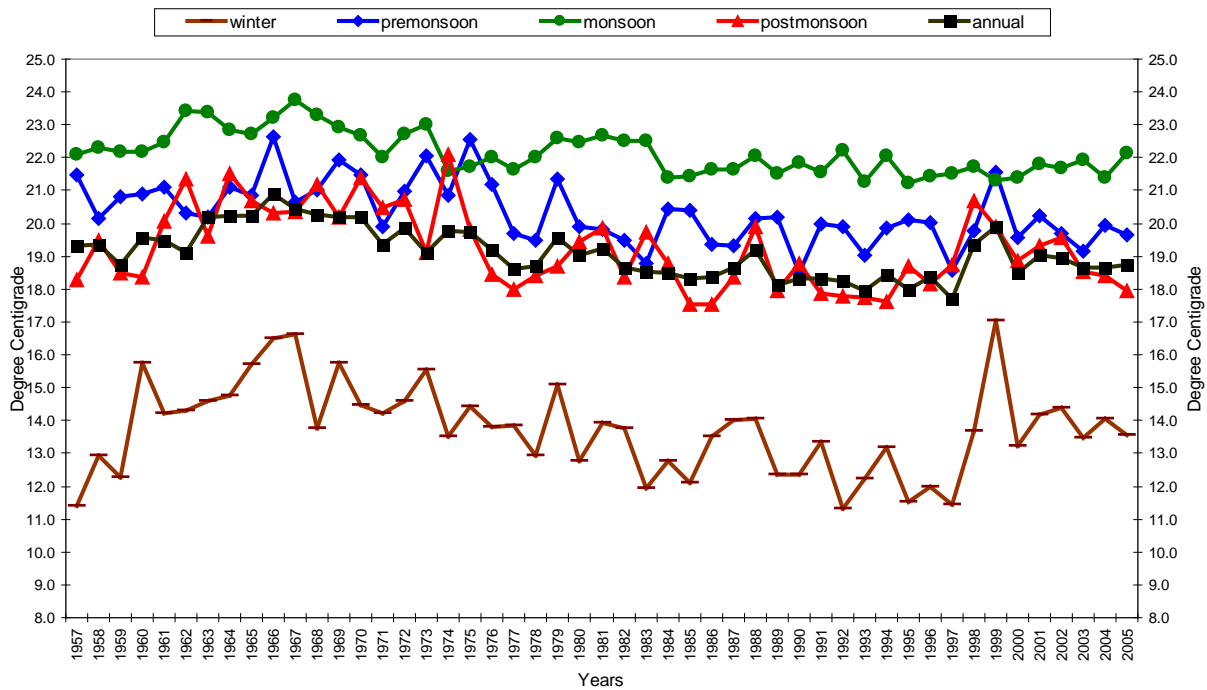


Fig. 3. Showing mean annual and season-wise temperatures over Gangtok (1957-2005)

temperature and rainfall parameters, the some statistics related temperature and rainfall are presented and they are as follows. The mean monthly average maximum temperature values computed from the period 1957-2005 from January to December are 12.8 °C, 14.2 °C, 18.3 °C, 21.0 °C, 21.7 °C, 22.2 °C, 22.0 °C, 22.4 °C, 21.5 °C, 20.9 °C, 17.7 °C and 14.6 °C respectively. The mean seasonal maximum temperatures for winter, pre monsoon, summer monsoon, post monsoon and annual are 13.5 °C, 20.3 °C, 22.0 °C, 17.7 °C and 19.1 °C respectively. Similarly, the mean monthly average minimum temperature values computed from the data set for the period 1957-2005 from January to December are 4.4 °C, 5.7 °C, 8.9 °C, 11.7 °C, 13.8 °C, 16.2 °C, 16.8 °C, 16.7 °C, 15.6 °C, 12.5 °C, 8.8 °C and 5.9 °C respectively. The mean seasonal minimum temperature for winter, pre monsoon, summer monsoon, post monsoon and annual are 5.3 °C, 11.5 °C, 16.3 °C, 10.6 °C and 11.4 °C respectively. The mean monthly average rainfall values calculated from the data set for the period 1957 – 2005 from January to December are 32.6 mm, 62.6 mm, 135.5 mm, 270.3 mm, 523.9 mm, 630.9 mm, 658.0 mm, 578.9 mm, 464.6 mm, 175.6 mm, 40.0 mm, 21.2 mm respectively. The average annual, winter, pre monsoon, summer monsoon and post monsoon rainfalls are 3611.7 mm, 95.2 mm, 947.4 mm, 2332.3 mm and 236.9 mm respectively as calculated from the data period 1957–2005. The annual and summer monsoon

rainfalls for the period 1957 – 2005 has been shown in Fig. 1 and month-wise average rainfalls for the period 1957 – 2005 are shown in Fig. 2. Similarly, the month-wise average maximum temperatures are shown in Fig. 3 and the season-wise temperatures for the period 1957 – 2005 are presented in Fig. 4. The average maximum temperature, average minimum temperatures and total rainfalls on monthly, seasonal and annual time scales are also presented in Table 1. From the Fig. 1, it can be seen that highest annual rainfall of 4422.5 mm occurred in the year 1977 and the lowest annual rainfall of 3030.2 mm occurred in the year 1989. The summer monsoon seasonal rainfall was highest with 2929.4 mm in the year 1987 and the lowest summer monsoon seasonal rainfall was 1915.2 mm in the year 2004. It can also be seen from the same Fig. 1 that in 26 years the annual rainfall was above the long period average rainfall and in the remaining 21 years the annual rainfall was below the long period average rainfall. In case of summer monsoon seasonal rainfall the seasonal rainfall in 21 years was above the long period average and in the remaining 26 years it was below the long period average.

Earlier studies done on temperature and rainfall parameters indicated significant trends in those parameters. Hennessy and Suppiah (1999) studied data of daily heavy rainfall, total rainfall and number of rainy

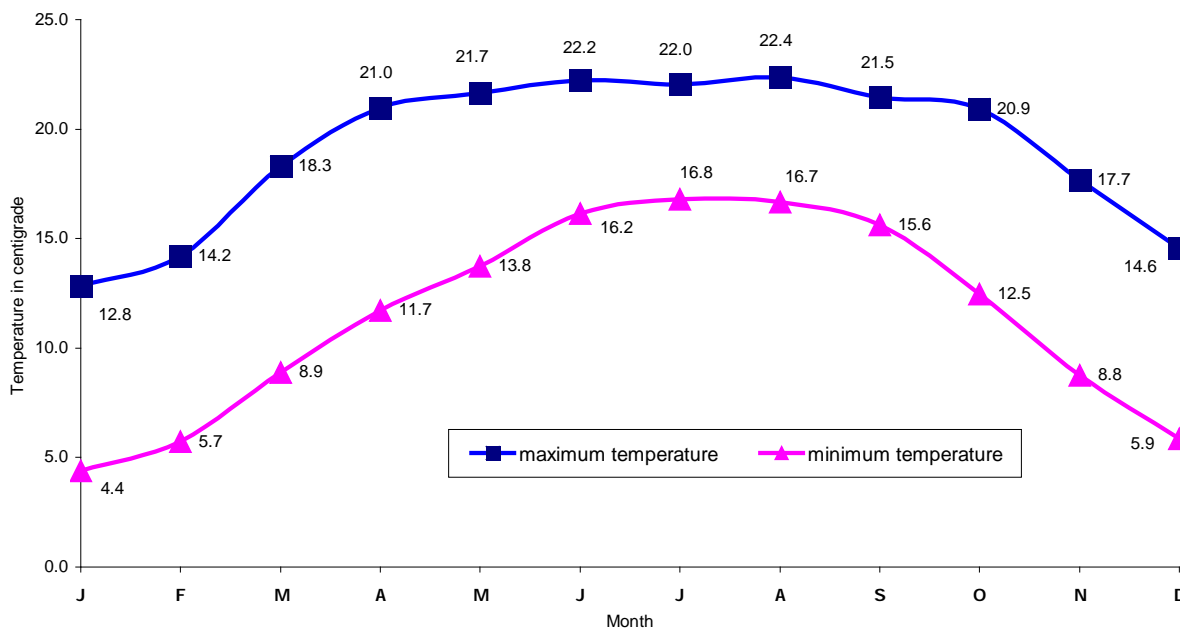


Fig. 4. Showing mean monthly average temperatures over Gangtok (1957-2005)

days from 379 meteorological stations over whole Australia and found many significant trends in the data sets. Similarly, Kothiyari and Singh (1996) studied temperature and rainfall trends over Ganga basin and long-term data on monsoon, annual rainfall and average annual temperature, annual maximum temperature for India as a whole. The study showed rainfall variables decreased and temperature variables increased trend. The study of Ochlert (1986) showed trends in atmospheric temperature from 850 hPa to 300 hPa using RS/RW meteorological data. The trends were not significantly different from zero but showed greenhouse type profile. The observational data showed more cooling than the models. Furthermore, Ventura *et al.* (2002) analyzed the historical meteorological data for the period 1952-1999 and found increasing trends in annual temperature and significant negative trends in annual total rainfall.

In this paper, the mean monthly, seasonal and annual maximum, minimum temperature and rainfalls have been analyzed using the seasonal Kendall test trend. The statistics related to the analysis of maximum temperature are presented in Table 1. From Table 1, it is seen that the maximum temperature month-wise, season-wise and annual scale has shown decreasing trend and also from the same Table it is seen that the minimum temperature month-wise, season-wise and annual scale has shown increasing trend. From Table 1 it is also seen that the mean monthly rainfall in January, March, June, September and November months has shown decreasing trend and

mean monthly rainfall in remaining months has shown increasing trend. Coming to seasons, only mean seasonal rainfall of winter season has shown negative trend while mean seasonal rainfall of the rest of the season has shown positive trend.

From Table 1 it is seen that the annual, winter, pre monsoon and post-monsoon mean maximum temperature decreased at the rate 0.3 °C per decade with monsoon mean maximum temperature decreased by 0.2 °C. It can be seen that the annual rainfall has shown an increasing trend with estimated increase of approximately 49.6 mm per 10 years. It can be seen that the mean winter rainfall has shown a decreasing trend with approximately 0.7 mm per 10 years period. And the pre monsoon mean rainfall has shown an increasing trend with approximately 20.3 mm per decade. It can be seen that the summer monsoon rainfall has shown an increasing trend with approximately 5.6 mm per 10 years period and the mean post monsoon rainfall has shown an increasing trend with approximately 11.7 mm per 10 years period. In case of temperatures, from the same Table 1 it can be seen that mean annual maximum temperature has shown a decreasing trend with approximately 0.3 °C per 10 years period and the mean winter season, pre-monsoon season and post-monsoon season maximum temperature has shown the decreasing trend as that of the annual mean maximum temperature during the same period. It can be seen that the mean monsoon maximum temperature has shown a decreasing trend with approximately 0.2 °C per 10 years period.

TABLE 1
Showing statistical parameters and observed trends in respect of maximum temperatures/minimum temperatures/rainfalls for the period 1957-2005

Month/season	Average maximum temperature (°C)	Average minimum temperature (°C)	Total rainfall (mm)	Trend per decade		
				Maximum temperature	Minimum temperature	Total rainfall
January	12.8	4.4	32.6	-01.0	+00.6	-02.7
February	14.2	5.7	62.6	-01.3	+00.9	+06.5
March	18.3	8.9	135.5	-01.5	+01.1	-12.7
April	21.0	11.7	270.3	-01.8	+01.3	+44.6
May	21.7	13.8	523.9	-01.9	+01.5	+50.7
June	22.2	16.2	630.9	-02.0	+01.8	-56.0
July	22.0	16.8	658.0	-02.0	+01.8	+67.9
August	22.4	16.7	578.9	-02.1	+01.9	+62.3
September	21.5	15.6	464.6	-01.9	+01.8	-41.7
October	20.9	12.5	175.6	-01.8	+01.5	+20.8
November	17.7	8.8	40.0	-01.5	+01.2	-02.0
December	14.6	5.9	21.2	-01.2	+00.8	+01.8
Annual	19.1	11.4	3611.7	-00.3	+00.2	+49.6
Winter	13.5	5.3	95.2	-00.3	+00.2	-00.7
Pre-monsoon	20.3	11.5	947.7	-00.3	+00.1	+20.3
Monsoon	22.0	16.3	2332.3	-00.2	+00.2	+05.6
Post-monsoon	17.7	10.6	236.9	-00.3	+00.3	+11.7

From the same Table 1 it can be further seen that the mean annual minimum temperature has shown an increasing trend with approximately 0.2 °C per 10 years period, the mean winter season minimum temperature has shown an increasing trend with approximately 0.2 °C, the mean pre monsoon minimum temperature has shown an increasing trend with approximately 0.2 °C, the mean summer monsoon minimum temperature has shown an increasing trend with approximately 0.2 °C and the mean post monsoon season minimum temperature has shown an increasing trend with approximately 0.3 °C per decade. From Table 1 again, the mean monthly maximum temperatures from January to December all showed negative trends with values -01.0, -01.3, -01.5, -01.8, -01.9, -02.0, -02.0, -02.1, -01.9, -01.8, -01.5 & -01.2 respectively per decade and mean monthly minimum temperatures from January to December all showed positive trends with values +00.6, +00.9, +01.1, +01.3, +01.5, +01.8, +01.8, +01.9, +01.8, +01.5, +01.2 & +00.8 respectively per decade.

The monthly rainfalls from January to December all showed positive trends except for the months January, March, June, September and November with values -02.7, +06.5, -12.7, +44.6, +50.7, -56.0, +67.9, +62.3, -41.7, +20.8, -02.0 & +01.8 respectively per decade.

5. The analysis of the data month-wise and season-wise and annual scale showed significant increasing and decreasing trends over the selected station. The above study indicated clearly an increase in the night temperature, decrease in the day temperature on monthly, seasonal and annual time scale. The above study further indicated increased rainfall except during the months of January, March, June, September and November on monthly scale, except winter on seasonal scale. Warmer nights and cooler days with increased rainfall activity indicated by the study.

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